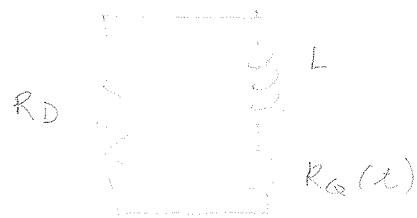# SSC DETECTOR SOLENOID DESIGN NOTE #18

TITLE: Quench Safety I: Choice of Current Densities

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CONCLUSION

A 4-m coil module, with a conductor current density of ~3000 A/cm2, will
be safe against a quench and will have a sufficiently low surface heat flux. A
2-m module with ~5000 A/cm2 will be safe on quench, but the surface heat
flux is a bit high. A current density of 1600 to 1800 A/cm2 will permit the
coil modules, of whatever size, to be electrically connected into 8-m units.

I. Calculate the maximum current density that is consistent with quenching safety.

If we ignore the mutual inductance between coil modules and if $R_D > R_G(t)$, the current decay is:

$$I(t) = I_0 e^{-\frac{R_D}{L} t} \quad ; \quad J(t) = J_0 e^{-\frac{R_D}{L} t}$$

and

$$\int_0^\infty J^2(t) \, dt = \frac{1}{2} J_0^2 \frac{L}{R_D} = U/\Omega_m) \quad (\text{units}, \ldots)$$

Solving for J_0:

$$J_0^2 = \frac{2 \, U/\Omega_m)}{L/R_D} \quad ; \quad J_0 = \sqrt{\frac{2 \, U/\Omega_m)}{L/R_D}}$$

Thus let $\Theta_m = 100K$, with $RRR = 100$, $(\rho_a = \ldots \Omega - m)$, then

$$U/\Omega_m) = 4 \times 10^{16} \, A^2 - s - m^{-4}$$

and

$$J_0(\Theta_m = 100K) = \frac{3.74 \times 10^8}{\sqrt{L/R_D}} \quad A - s^{1/2} - m^{-2}$$

If we limit the terminal voltage to 500V

then

$$R_0 = \ldots \Omega, \text{ for } \ldots \text{ magnet,}$$

independent of ...

Solving ... for ... inductance
... ...:

Coil length (in)	L (μH)	R (Ω)	...
8	49.6	0.1	1679
4	18.1	0.1	2180
?	?.?	0.1	1032

... ... $(?)^{?}$ ...

II. ... ...
... ...

Magnet	...	...	...
... R.B.	4.9	6640	
...	2.8	9560	
... B.C.	4.5	3100	
...	8.0	4078	200
... 2opar	8.0	2037	
... Y.Y	7.4	4926	210
...	5.2	1586	124

III. Current heat loss at $J_{cond} = 3000 \, A/cm^2$
and $I = 5 kA$ (a 4 m coil insulated)

$P_{cond} \sim A_{cu} = \frac{5000}{3000} \, cm^2 = 1.7 \, cm^2$

If the conductor were square, $a = b = 1.3 \, cm$

the heat flux $= \dfrac{I^2 \rho}{\gamma (ab) 2(a+b)}$

where $\gamma =$ fraction of surface wetted

Parameter	Initial	Self Force	Self Force
Current (A)	2866	5000	5000
conductor area (cm²)	4.4 × 10⁻³	4.2 × 10⁻³	4.0 × 10⁻³
area (cm²)	0.825	1.7	1.0
J_cond (A/cm²)	4566	3000	5000
ρ (ohm-cm)	10⁻⁸	10⁻⁸	10⁻⁸
$\frac{I^2\rho}{2 ab \, 2ab}$ (W)	0.0325	0.0325	0.0325
$\frac{I^2\rho}{2 ab \, 2(a+b)}$ (W)	0.150	0.170	0.250
γ	0.50	0.50	0.50

IV. Remarks

For a maximum hot-spot temperature of 100K, the conductor current density (3000 A/mm²) is low in comparison with other cryostable magnets, but not absurdly so. The surface heat flux, [...] which is 25% less than [...] in a 4-m module than in [...] TF criostable, again [...] absurd.

A more detailed [...] analysis [...]

V. Conclusion

A 4-m coil module, with a conductor current density of ~3000 A/mm², will be [...] quench and will have a sufficiently low surface heat flux. A 3-m module with ~5000 A/mm² will be safe on quench, but the surface heat flux is a bit high.